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REGIONAL STABILITY IN THE ELLIOT LAKE MINES
PART 2: THE DENISON-PANEL BOUNDARY

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INTRODUCTION

The first report in this series evaluated pillar stability along the Denison-Quirke boundary using electrical analog models. It was found that pillar stresses at a distance of 250 ft from the boundary were more-or-less the same as those estimated using the tributary area theory. Previously developed empirical equations were used to estimate pillar strength. Using these estimates of pillar stress and strength, guidelines were developed for safety factors and extraction ratios in zones 250 ft wide on either side of the boundary and these were related to depth below surface, dip and reef thickness. This study is a continuation, using the same techniques to evaluate pillar stability along the Denison-Panel boundary.

Fig. 1 shows a mine plan spanning the Denison-Panel boundary. At present, Denison has completed primary stoping part-way along the boundary, whereas mining at Panel has not reached the boundary. Information on thickness of the uranium reef(s) below present workings is fairly scanty, consequently, a complete evaluation cannot be done below present workings. In Fig. 1 the area for a distance of 250 ft on either side of the boundary is divided into blocks about 500 ft long and each block is identified by a number in a circle. Below block 9 on the Denison side is shown the five year mining plan rather than the present layout.

The basic equations for evaluating pillar stability are as follows:

$$\text{Safety Factor (SF)} = \frac{\text{Pillar strength}}{\text{Pillar stress}} \qquad \text{Eq. 1}$$

$$\text{Pillar Strength} = 26,000 \frac{W^{.5}}{H^{.75}} \qquad \text{Eq. 2}$$

0
400 ft
N
PANEL 10
PANEL 12
PANEL 14
PANEL 16
PANEL 18
PANEL 20
PANEL 22
PANEL 24
PANEL 26
202
203
201
ROMAN ISLAND
RIO-ALGOM
PANEL MINE
DENISON MINE

where: W = pillar width, ft

H = pillar height, ft

$$\text{Pillar Stress} = \frac{So}{1 - R} \qquad \text{Eq. 3}$$

where: So = premining stress perpendicular to dip

R = extraction ratio

and: $So = 1.15\ D \cos^2\alpha + (1200 + 0.87D) \sin^2\alpha$

where: D = depth below surface, ft

α = dip of reef

Substituting equations 2 and 3 into equation 1 gives:

$$S.F. = \frac{26,000\ W^{.5}\ (1 - R)}{So\ \ H^{.75}} \qquad \text{Eq. 4}$$

MINING LAYOUT AT DENISON

As shown in Fig. 1, in the upper levels (panels 10 and 12) at Denison, stopes 65 ft wide were extracted leaving 20 ft wide rib pillars. With subsequent recovery of the up-dip sill pillars the extraction is about 75%. In panels 14 and 16 the reef is almost flat and 30 ft sections were taken out of the rib pillars giving an extraction of about 80%. For present workings, a typical layout is to drive headings 25 ft wide along strike spaced at 50 ft centres with a 25 ft wide intervening pillar. Sections up to 55 ft wide are then removed from the strike pillars leaving rectangular pillars 25 ft by 35 ft and giving an extraction of up to 80%.

The dip, depth, premining stress (So), reef thickness and pillar width are listed in Table 1 for each block on the Denison side of the boundary.

TABLE 1

Mining Parameters at Denison

Block No.	Dip Degrees	Depth ft	So psi	H ft	W ft	Extraction Ratio R % SF 1.25	SF 1.50	SF 1.75	Present R %	Present SF
1	40	750	1270	13	20	90	89	87	77	3.1
2	36	920	1380	17	20	87	85	83	76	2.4
3	36	850	1310	13	20	90	88	86	74	3.3
4	20	750	980	18	20	90	89	87	82	2.4
5	31	730	1100	20	25	90	88	86	78	2.7
6	33	1040	1460	22	25	86	83	80	78	1.9
7	8	1150	1340	24	25	86	83	80	80	1.8
8	30	1300	1700	20	25	85	81	78		
9	20	1480	1790	18	25	85	82	79		
10	24	1650	2020	$R = 1 - H^{-.25} \times$		.097	.117	.136		
11	25	1600	1970			.095	.114	.133		
12	23	1560	1910			.092	.110	.129		
13	14	1460	1720			.083	.099	.116		
14	18	1500	1800			.087	.104	.121		

So = premining stress perpendicular to dip
H = reef thickness, i.e., pillar height
W = minimum pillar width
R = extraction ratio
S.F = safety factor

Mining has progressed down to block 9 and using Equation 4 the extraction ratios corresponding to safety factors 1.25, 1.5 and 1.75 have been calculated. Where mining has been completed the extraction rate was determined using a planimeter (excluding the boundary pillar) and the present safety factors calculated, which are shown in Table 1, range from 1.8 to 3.3.

As mentioned previously, below existing workings information on reef thickness is uncertain, however, it is possible to calculate the extraction ratio in terms of reef thickness. In these unmined areas Denison intends to leave pillars with a width/height ratio of one, hence W = H. Consequently, Equation 4 can be rearranged to:

$$R = 1 - \frac{S.F \times So \times H^{.75}}{26,000\ H^{.5}}$$

or,
$$R = 1 - H^{.25}\left(\frac{S.F \times So}{26,000}\right) \qquad \text{Eq. 5}$$

The values of the term in the brackets in Equation 5 are listed in Table 1 for blocks 10 to 14 and safety factors 1.25, 1.50 and 1.75. As an example, suppose in block 12 the reef thickness is 25 ft, then the extraction ratio for a safety factor of 1.50 is:

$$R = 1 - 25^{.25} \times .110$$

$$= 75.5\%$$

MINING LAYOUT AT PANEL

Panel Mine was originally in production between 1958 and 1961, and then reopened in 1979. Present mining layout is for trackless operations with stopes and pillars being laid out at an angle to dip to give a gradient of

14%. The long rib pillars are spaced at 75 ft centres, but as yet pillar width has not been fixed. Dip, depth, premining stress (So) and reef thickness are listed in Table 2 for each block on the Panel side of the boundary. Down to block 6, reef thickness can be reliably estimated from corresponding thicknesses on the Denison side. Since pillar width has not been fixed, it was decided to calculate pillar width and corresponding extraction ratio for safety factors 1.25, 1.50 and 1.75 for blocks 1 to 6.

When the stopes and pillars are regular and fairly long the extraction ratio can be approximated by the two dimensional case:

$$R = \frac{75 - W}{75} \qquad \text{Eq. 6}$$

where distance between pillar centres is 75 ft.

Substituting Equation 6 in Equation 4 and rearranging, produces:

$$W = H^{.5} \times \left(\frac{S.F \times So \times 75}{26,000}\right)^{.667} \qquad \text{Eq. 7}$$

This equation was used to calculate pillar widths and then Equation 6 to obtain extraction ratios. Where the reef thickness is uncertain the values of the term in the brackets in Equation 7 are listed in Table 2 for blocks 7 to 11 and safety factors 1.25, 1.50 and 1.75. As an example, suppose in block 9 the reef thickness is 15 ft, then the pillar width for a safety factor of 1.50 is:

$$W = 15^{.5} \times 3.93$$

$$= 15 \text{ ft}$$

and the corresponding extraction ratio is:

$$R = \frac{75 - 15}{75} = 80\%$$

TABLE 2

Mining Parameters at Panel

Block No.	Dip Degrees	Depth ft	So psi	H ft	Safety Factor 1.25		Safety Factor 1.50		Safety Factor 1.75	
					W ft	R %	W ft	R %	W ft	R %
1	40	700	1220	13	10	87	11	85	12	84
2	40	650	1170	14	10	87	11	85	12	84
3	30	700	1050	20	11	85	12	84	14	81
4	32	990	1400	23	14	81	16	79	18	76
5	11	1120	1320	26	14	81	16	79	18	76
6	26	1210	1550	19	14	81	16	79	17	77
7	23	1470	1810	$W = \sqrt{H} \times$	3.49		3.95		4.37	
8	25	1590	1960		3.69		4.16		4.61	
9	23	1460	1800		3.48		3.93		4.36	
10	14	1400	1660		3.30		3.73		4.13	
11	18	1440	1730		3.39		3.83		4.24	

So = pre mining stress perpendicular to dip
H = reef thickness, i.e., pillar height
W = minimum pillar width
R = extraction ratio

GUIDELINES

The suggested guidelines developed for the Denison-Quirke boundary would also apply to the Denison-Panel. To iterate:

1. For a distance of 250 ft from the Denison-Panel boundary the pillars should be designed with a minimum safety factor of 1.5 for primary stoping operations. The depth below surface, reef thickness and pillar width will determine the corresponding extraction ratio.
2. Above an extraction ratio of 85% pillar stresses increase rapidly and estimates are unreliable, hence, 85% should be the maximum during primary stoping.
3. Until both mining companies have completed primary mining along the boundary, no pillar recovery operations should be done in the 250 ft zones which would reduce the safety factor below 1.5.
4. Any subsequent pillar recovery in the 250 ft zones should not reduce the safety factor below 1.3 unless additional support, (e.g., backfill, concrete pillars) is provided. If possible operations should be coordinated including any possible future recovery of the boundary pillar by mutual agreement.